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SEATIDE ANALYSIS PROCESS. VOLUME IV. RELATIVE WORTH MODEL (RWM)--ETC(U)
JAN 74 DAAB09-72-C-0062

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SEATIDE

SEATIDE ANALYSIS PROCESS

VOLUME IV

RELATIVE WORTH MODEL (RWM)

USERS MANUAL

REPORT NO. 00.1636
JANUARY 1974
(CONTRACT DAAB09-72-C-0082)

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JAN 13 1978
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VOUGHT SYSTEMS DIVISION
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(6) # SEATIDE ANALYSIS PROCESS.

VOLUME IV.

RELATIVE WORTH MODEL (RWM)

USERS MANUAL.

(14) VSD-
REPORT NO 00.1636 -VOL-4

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(CONTRACT DAAB09-72-C-0062

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FOREWORD

(U) This report was prepared by the Vought Systems Division, LTV Aerospace Corporation, P.O. Box 6267, Dallas, Texas 75222 under U. S. Army Electronics Command Contract DAAB09-72-C-0062. The work was initiated under the direction of Captain R. A. Dowd, USN and completed under Captain W. A. Greene, USN, Chief, Long Range Forecast Division, Directorate of Estimates, Defense Intelligence Agency (DIA-DE-1).

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Mr. G. S. McCorkle	Propulsion
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(U) This report has been prepared in the following volumes:

Volume	Classification	Title
I	S	Summary
IIA	U	Naval Engagement Model (NEM) - Users Manual
IIB	U	NEM - Appendices A - I
IIC	S	NEM - Appendices J - M
IID	U	NEM - Appendix N
IIIA	U	Cruise Missile - Concept Generation and Screening Model (CM-CGSM) - Users Manual
IIIB	U	CM-CGSM Appendices A-B
IIIC	S	CM-CGSM Appendix C
IIID	U	CM-CGSM Appendices D-G
IIIE	U	CM-CGSM Appendix H
IV	U	Relative Worth Model (RWM)

ABSTRACT

(U) The SEATIDE Analysis Process is a semi-automated procedure for the generation of time-phased, high value cruise missile weapon systems concepts, together with the supporting technology and intelligence indicators which would reflect that these technological goals are being achieved. The SEATIDE process can also be used to evaluate the effectiveness of fixed force levels, existing forces in SAL environments, or Naval defenses.

(U) The Defense Intelligence Agency, through its Directorate of Estimates, and The Advanced Research Projects Agency (ARPA) have sponsored the development of this computer based analysis at the weapon system and Naval force structure level. A previous process, RIPTIDE, was developed for DIA for use in analysis of strategic missile systems.

(U) Generic to the SEATIDE Analysis Process are three major computer models: The Naval Engagement Model (NEM), Cruise Missile Concept Generation and Screening Model (CM-CGSM) and Relative Worth Model (RWM). The NEM evaluates force effectiveness, tactics, and task force configurations; the CM-CGSM enables definition and selection of candidate, advanced cruise missile system concepts; and the RWM permits assessment of worth in accordance with a variety of objective and subjective criteria. Each of these models has been checked out by DIA.

(U) In addition to exercising the computer models, there are several other analytical and engineering tasks to be performed, e.g., the identification of areas of current interest and the associated criteria and potential concepts, the creation of a foreign technology data bank in a format needed by the computer models, the engineering of concepts to the required detail, and the use of a verification analysis loop.

TABLE OF CONTENTS
VOLUME IV- RELATIVE WORTH MODEL (RWM) USERS MANUAL (U)

LIST OF ILLUSTRATIONS

REFERENCES

1. "A General Linear Ranking Model," by L. D. Gregory PhD Dissertation, SMU 1968, Order No. 69-3296, University Microfilms, Ann Arbor, Michigan

SECTION I

INTRODUCTION

(U) On 28 June 1972, the Vought Systems Division, a division of LTV Aerospace Corporation, contracted with the Defense Intelligence Agency (DIA) to develop the SEATIDE Analysis Process in support of the DIA Long Range Forecast Division (DE-1). The SEATIDE Analysis Process is defined to be:

> " .... a semi-automated procedure for the generation of time phased, high value naval cruise missile system concepts, together with the supporting technology and the intelligence indicators which would reflect that these technological goals are being achieved .... "

(U) Generic to the SEATIDE Analysis Process are three major computer models: the Naval Engagement Model (NEM), the Cruise Missile Concept Generation and Screening Model (CM-CGSM), and the Relative Worth Model (RWM). This volume presents a Users Manual for the RWM only. Users Manuals for the other models are found in Volumes IIA and IIIA, respectively.

(U) The RWM is written in FORTRAN IV computer language and is compatible with the DIAMS IBM 360/65 computer system at Arlington Hall, Virginia.

(U) This manual is written with three objectives in mind:

(a) To serve the systems analyst.

(b) To serve the programmer who will implement and update the computer programs.

(c) To serve the computer operations personnel with a source for preparing detailed computer operating instructions.

In addition, a number of appendices are included to give a broader understanding of the purpose, approach, and/or techniques used in various major portions of the computer models. Appendix A is a detailed listing of the FORTRAN Source Program. Other information, of interest only to the systems analyst, is to be found in Volume III and its Technical Appendices.

SECTION II

DESCRIPTION

1. PURPOSE

(U) The purpose of the Relative Worth Model (RWM) is to provide DIA with a computer model within the SEATIDE Analysis Process to rank high value advanced cruise missile systems concepts using a variety of objective and subjective criteria. While the model is quite general, the terminology and variables used in its application to SEATIDE are those used in the NEM and CM-CGSM. These are: WORTH1, WORTH2, and COST*, quantities which are available for each candidate concept which survives the screening process in the CM-CGSM. Other variables which can be attached to each candidate are such things as: Years to Achieve IOC, Technological Risk, Use of Critical Materials, etc. Each of these may have a bearing to a greater or lesser degree on the ranking of the candidates from the National Planning point of view. The purpose of the Relative Worth Model is to provide DIA a quantitative way to inject the judgment of qualified experts into assessing the relative importance of all variables and their combined influence on the resultant ranking. An error analysis is also provided which establishes rank bounds which reflects the system analysts degree of certainty on his judgment.

2. ASSUMPTIONS AND APPROACH

(U) The RWM assumes that each system to be ranked can be described by a common set of variables, $x_1, x_2, \ldots, x_n$ (x_1 might be WORTH1, x_2 might be WORTH2, etc.). It also assumes that in a given context of mission to be performed (requirement to be met), resources available, policy and other constraints, that there exists a Worth Function which measures the "desirability" of each system relative to another, and that the worth is a function of the variables x_1 to x_n, i.e., that for the i^{th} system there is a Worth W_i given by

$$W_i = F(X_i) \qquad (1)$$

where $X_i = (x_{i1}, x_{i2}, \ldots, x_{in})$

$= $ system variables

* In this application, COST is defined as system weight. In the event, a costing methodology is added to the SEATIDE process at a later date, no heading changes will be required.

(U) If such a Worth Function were explicitly known, the various systems could be ranked by direct substitution of their variables into the function. However, where the function is not explicitly known, or uncertainties in the data exist, additional methodology is needed.

2.1 The Ranking Index

(U) Under certain quite general assumptions, Reference 1, a Worth Index W* may be defined by linearizing the Worth Function using Taylor's series with a remainder. Thus, given m systems to be compared, each described by n variables x_j (j=1 to n), we may then think of having an (m x n) matrix X of data describing the m systems, i.e.,

$$X = (x_{ij}) \tag{2}$$

where x_{ij} = value of the jth variable of the ith system.

As shown in Reference 1, we may now define the Worth Index W* as

$$W_i^* = \sum [(x_{ij} - c_j) \bullet t_j)] + F(\underline{c}) \tag{3}$$

where $\underline{c} = c_1, c_2, \ldots, c_n$ = a baseline system or coordinate origin

t_j = trade factor j, (j=1 to n)

$$= \left\{ \frac{\partial F}{\partial x_j} \Big/ \frac{\partial F}{\partial x_b} \right\}_{\underline{c}} = \left\{ - \frac{\partial x_b}{\partial x_j} \right\}_{\underline{c}}$$

Thus, we see that the "trade factor" t_j corresponding to the jth system variable is (from a mathematical point of view) the constrained derivative of some "baseline" variable x_b with respect to the jth variable, evaluated at the reference point $\underline{c}$. It can be shown that within the limits of linearization of the region of interest that for two system p and q,

$$W_p^* > W_q^* \quad \text{if and only if} \quad W_p > W_q \tag{4}$$

i.e., that two systems p and q can be ranked in the same order using the Worth Index as they would be ranked using the Worth Function.

(U) Estimation of trade factors is discussed in Appendix B.

2.2 Sensitivity Analysis - Rank Bounds

(U) If we assume error bounds e_j in our estimates of the trade factors t_j, then for two systems p and q it can be shown (Reference 1) that their relative ranks remain unchanged for any combination of errors e_j if and only if

$$k_{pq} = \frac{|W_p{*} - W_q{*}|}{\sum_{j=1}^{n} |x_{pj} - x_{qj}| \, |e_j|} > 1 \qquad (5)$$

By comparing all possible pair of systems a rank sensitivity matrix

$$K = (k_{pq}), \quad (p, q = 1, \ldots, m) \qquad (6)$$

can be used to establish rank bounds (r_1, r_2) on each system rank. These rank bounds are the highest and lowest ranks achievable by the system for any combination of errors with the error bounds e_j. These rank bounds may be exhibited as shown in Appendix B.

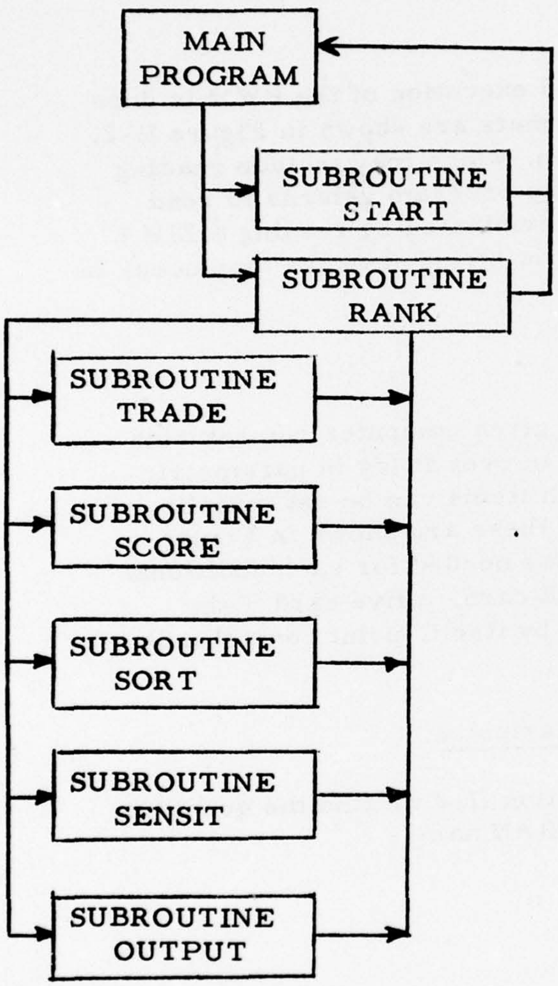
3. TOP LEVEL FLOW

(U) The RWM top level flow is presented in Figure II-1 and is discussed below.

(U) The RWM consists of a MAIN program and seven subroutines. No link overlay is required. The MAIN program calls Subroutine START which reads a PCODE card which identifies the data or case being run, etc., a five line TITLE and up to 520 lines of COMMENTS, 80 characters to the line. Upon command (see section II. 4) it reads data and then calls Subroutine RANK which then calls the other subroutines as needed. The function of each subroutine is shown in Figure II-1.

FIGURE II - 1

RELATIVE WORTH MODEL TOP LEVEL FLOW (U)



Controls and executes Data INPUT options. Calls Subroutines START and RANK. Calls EXIT to terminate run.

Inputs Run Identification CODE, TITLE page information, and COMMENTS.

Calls five execution/output subroutines. Calculates System RELATIVE WORTH.

Calculates Parameter TRADE FACTORS.

Calculates System WORTH based on a set of average Trade Factors.

Determines System RANK from System WORTH

Calculates Ranking Sensitivity RANK BOUND and outputs SENSITIVITY MATRIX as optioned.

Executes Ranking Model OUTPUT options.

4. INPUT

(U) RWM input data are presented in this section, along with a general discussion of program control parameters. Input parameters are defined and input card formats illustrated.

4.1 Control Parameters

(U) Control during setup and execution of the RWM is done by a set of ZIP code cards. ZIP card formats are shown in Figure II-2. Each ZIP card initiates a particular action, which may include reading additional control parameters, and then the program returns to read another ZIP card. The computer run is terminated by reading a ZIP 9 card. A detailed discussion of ZIP cards is included where they occur in Figures II-3 thru II-7.

4.2 Initialization Input

(U) All RWM input data in a given computer run remains unchanged until a replacement set is read in over it (as in parametric variations in a single JOB). Hence certain items can be set initially and left alone thereafter. A typical set of these are shown in Figure II-3, although any or all could be changed as needed for each additional variation. This includes the initial PCODE card, a five card Title which gets printed during output on a page by itself, print control indices, and Base Worth and System Variables.

4.3 Base Worth & Base System Variables

(U) From Equation (3) in section II.2 we find the quantities $\underline{C}$ and $F(\underline{C})$ which have the following FORTRAN names

XBASE(I) $= c_i$, $i = 1$ to n

BWORTH $= F(\underline{C})$

These can be any convenient numbers (including zeros), but if they are chosen from some baseline system the Worth Index has a visible relation to that of the baseline system (as well as a numerical ranking). These are shown as items M and N in Figure II-3.

4.4 Trade Factor Input

(U) Trade Factors are defined in equation (3) in section II-2 and error bounds e_j on Trade Factor t_j are shown in equation (5). Estimation of these are discussed in Appendix B. However, it may be

said here that they are usually estimated as a lower and upper bound. These upper and lower bounds are entered as shown in Figure II-4. The average is taken as the Trade Factor, and half of their difference is taken as the error bound e_j. If there are n system variables there are n sets of Trade Factors $t_1, t_2, \ldots, t_n$.

4.5 System Names

(U) System names may be left blank or chosen at the convenience of the user. The RWM keeps track of systems by system number. These are shown in Figure II-5.

4.6 System Data

(U) System data is defined as the x_{ij} in equation (2) in section II-2. For each system (identified by system number i) there are n values $x_{i1}, x_{i2}, \ldots, x_{in}$ describing that system. These are entered 7 to the card as shown in Figure II-6.

4.7 Execution and Parameter Variation

(U) After all data has been read, a ZIP 8 control card causes execution of a ranking and sensitivity analysis. Output is then printed according to the print control indices previously read in. After this cycle is complete the computer run may be terminated with a ZIP 9 control card, or as shown in Figure II-7 another cycle may be set up and executed. In the example in Figure II-7 only the PCODE card and the Trade Factor data was changed. But any other input may be changed either by complete replacement, or as in the case of Trade Factors, System Names, or System Data, by single lines. These partial replacements of input data are shown in Figure II-8.

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FIGURE II-2

RWM - CONTROL CARD FORMAT

PROGRAM	NAME	
ROUTINE	UNIT	DATE
	EXT.	PAGE OF

1. Control Card as follows.

ZIP	AA	BB	CC	DDDDDDDD	EEEE	FFFF	GGGG	HHHH	NN → ← NN
Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	ZCØDE(10) THRU ZCØDE(19)
A4	I2	I2	I2	I10	I5	I5	I5	I5	10A4

where:

Z1 = ZIP, CØNTRØL CARD IDENTIFIER
Z2 = DATA RØUTING CØDE
Z3 = DATA RØUTING CØDE
Z4 THRU Z9, UNUSED
Z10 THRU Z19, PLAIN TEXT DESCRIPTIØN ØF CØNTRØL CARD PURPØSE

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FIGURE II-3

RWM - INITIALIZATION INPUT

Variables	Definition
A	Zip Code 5, first card in a data deck.
B	Plain text purpose of Zip 5.
C	PCODE card. A one line identifier which gets printed at the top of each page of output.
D	A five line title.
E	Comment cards (if any). Comments are terminated by two blank cards. Maximum of 520 cards.
F	Two miscellaneous constant cards. Not used but needed for read purposes.
G	Zip code 3.
H	Plain text purpose of Zip 3.
J	Print control, in fields of five. A zero means do not print. 1. Print system ranks and worths 2. Print sensitivity matrix K 3. Print rank bounds 4. Specifies number of top ranked systems to put in sensitivity matrix K. If zero it puts all systems in K. 5. Print trade factors and bounds 6. Print system data
K	Zip code 1. Read base worth and base system variables.
L	NAMELIST NAM1. Begin reading.
M	BWORTH = Worth of a baseline system.
N	XBASE(I) = Value of variable I for baseline system.
P	NAMELIST NAM1. End reading.

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FIGURE II - 3

RWM - INITIALIZATION INPUT

PROGRAM | ROUTINE | NAM | UNIT | EXT. | PAGE | OF

TYPE | STATEMENT NO. | CONT. | FORTRAN STATEMENT | FORTRAN | IDENTIFICATION

LOCATION | CONT. | OPERATION | ADDRESS, TAG, DECREMENT | MAP

PAGE SERIAL | A | B | COBOL

```
ZIP 5  -A                                              READ PCØDE, TITLE  -B
DATA. PGM= RWM         RELATIVE WØRTH MØDEL(SAMPLE)                     RUN=74-01-18
                                                                          -C
                       NU7
                       RWM
                       VØUGHT SYSTEMS DIVISIØN                     D
                       LTV AERØSPACE CØRPØRATIØN
                       DALLAS, TEXAS 75222
              Blank                                                E
              Blank
  MISC               1                                             F
 XMISC             1.0
ZIP 3  -G                                          READ ØUTPUT PRINT ØPTIØNS  - H
  1     1     1     0     1     1  - J

ZIP 1  - K                                     READ BASE WØRTH & BASE SYSTEM VARIABLES
$NAM1   BWØRTH= 453.0, XBASE= 12.0, 105.0, 3.0, 1100.0, 16*0.0, $END
   L          M                    N                                P
```

II-11

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PAGE | LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

FIGURE II-4

RWM - TRADE FACTOR INPUT

Variables	Definition
A	Zip code 2.
B	Plain text purpose of Zip 2.
C	Integer in cols 1 - 5 uniquely identifying each trade factor. Must begin with 1 and proceed sequentially.
D	Name of trade factor, up to 8 letters in cols 11 - 18, plus 8 more in cols 21 - 28.
E	Lower bounds to trade factors* in cols 31 - 40.
F	Upper bounds to trade factors* in cols 41 - 50.
G	Blank card which terminates reading of trade factors and returns control to MAIN.

*NOTE: Sign of trade factor is negative if large values of its corresponding variable are less desirable.

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PROGRAM: FIGURE II - 4

ROUTINE: RWM - TRADE FACTOR INPUT

NAME / UNIT / EXT. / PAGE / OF

TYPE | STATEMENT NO. | CONT. | FORTRAN STATEMENT | FORTRAN | IDENTIFICATION

LOCATION (PAGE SERIAL) | CONT. | OPERATION (A, B) | ADDRESS, TAG, DECREMENT | MAP

COBOL

Location	Operation	Cols 31–40	Cols 41–64
ZIP 2 — A			READ TRADE FACTOR DATA — B
1	WEIGHT	-3.0	-28.0
2	RANGE	1.0	1.0
3	IØC	-6.0	-26.0
4	WHNT	-.00545	-.01455
C	Blank — G	E	F

D

II-13

PAGE | LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

FIGURE II-5

RWM - SYSTEM NAMES

Variables	Definition
A	Zip code 6.
B	Plain text purpose of Zip 6.
C	Integer in cols 1 - 5 uniquely identifying a system to be ranked.
D	System "name" in cols 11 - 50 corresponding to system number. May be coded to show significant characteristics for reference to its place in a CGSM output.
E	Blank card which terminates reading of system names and returns control to MAIN.

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PROGRAM | UNIT | DATE
ROUTINE | EXT. | PAGE OF

FIGURE II - 5

RWM - SYSTEM NAMES

LOCATION (PAGE SERIAL)	OPERATION	ADDRESS, TAG, DECREMENT		
ZIP 6 A			READ SYSTEM NAMES B	
1 C	LIQ	ROC - 24(LIGHT) D		
2	LIQ	ROC - 1(LIGHT)		
3	LIQ	ROC - 2(LIGHT)		
4	LIQ	ROC - 5(LIGHT)		
5	LIQ	ROC - 23(LIGHT)		
6	LIQ	ROC - 6(LIGHT)		
7	LIQ	ROC - 40(HVY)		
8	LIQ	ROC - 1(HVY)		
9	LIQ	ROC - 20(HVY)		
10	LIQ	ROC - 8(HVY)		
11	LIQ	ROC - 2(HVY)		
12	LIQ	ROC - 6(HVY)		
13	SOL	ROC - 6(HVY)		
14	SOL	ROC - 3(HVY)		
15	SOL	ROC - 7(HVY)		
16	SOL	ROC - 4(HVY)		
17	SOL	ROC - 14(HVY)		
18	SOL	ROC - 8(HVY)		
Blank E				

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PAGE LINE | OPERAND | AUTOCODER | IDENTIFICATION

FIGURE II-6
RWM - SYSTEM DATA

Variables	Definition
A	Zip code 7.
B	Plain text purpose of Zip 7.
C	Integer in cols 1-5 uniquely identifying a system to be ranked. Must correspond to integer used for system name.
D	Value of variable 1 in cols 11-20 (corresponds to trade factor 1)
E	Value of variable 2 in cols 21-30 (corresponds to trade factor 2)
F	Value of variable 3 in cols 31-40 (corresponds to trade factor 3)
G	Value of variable 4 in cols 41-50 (corresponds to trade factor 4)
H	Blank card which terminates reading system data and returns control to MAIN

NOTE: If there are more than 7 variables, place on succeeding cards in increasing order but with same number as C in cols 1-5.

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PROGRAM: FIGURE II - 6 | UNIT | DATE

ROUTINE: RWM - SYSTEM DATA | EXT. | PAGE OF

Page / Serial	Cols 11–15	Cols 21–25	Cols 31–35	Cols 41–45	Identification
ZIP 7 — A				READ SYSTEM DATA — B	
1 — C	11. — D	113. — E	3. — F	1100. — G	
2	11.	124.	3.	1100.	
3	12.	141.	3.	1100.	
4	12.	141.	3.	1100.	
5	13.	150.	3.	1100.	
6	13.	156.	3.	1100.	
7	11.	89.	3.	2200.	
8	11.	100.	3.	2200.	
9	12.	111.	3.	2200.	
10	12.	111.	3.	2200.	
11	12.	116.	3.	2200.	
12	13.	132.	3.	2200.	
13	11.	100.	4.	2200.	
14	11.	101.	4.	2200.	
15	12.	116.	4.	2200.	
16	12.	117.	4.	2200.	
17	13.	124.	4.	2200.	
18	13.	132.	4.	2200.	
Blank — H					

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FIGURE II-7

RWM - EXECUTION AND PARAMETER VARIATION

Variables	Definition
A	Zip code 8
B	Plain text purpose of Zip 8
C	Zip code 4
D	Plain text purpose of Zip 4
E	PCODE card. A one line identifier which gets printed at the top of each page of output.
F	Zip code 2
G	Plain text purpose of Zip 2
H	Integer in cols 1 - 5 uniquely identifying each Trade Factor. Must begin with 1 and proceed sequentially.
J	Name of Trade Factor, up to 8 letters in cols 11 - 18, plus 8 more in cols 21 - 28.
K	Lower bound to trade factors* in cols 31 - 40
L	Upper bound to trade factors* in cols 41 - 50
M	Blank card which terminates reading of trade factors and returns control to MAIN
N, P	Zip code 8. Executes new parameter variations entered since last Zip 8.
Q, R	Zip code 9. STOP. End of computer run.

*NOTE: Sign of trade factor is negative if large values of its corresponding variable are less desirable.

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NAME
UNIT **UNCLASSIFIED**
EXT. PAGE OF

FIGURE II - 7

RWM - EXECUTION AND PARAMETER VARIATION

PROGRAM
ROUTINE
TYPE | STATEMENT NO. | CONT. | FORTRAN STATEMENT | FORTRAN
LOCATION | CONT. | OPERATION | ADDRESS, TAG, DECREMENT | MAP | IDENTIFICATION
PAGE SERIAL | A | B | COBOL

```
ZIP 8 — A                                   B — EXECUTE RANKING & SENSITIVITY ANALYSIS
ZIP 4 — C                                   D — READ NEW PCØDE
                     E
DATA.PGM=RWM                    RWM VARIATIØN ØNE                    RUN=74-01-18
ZIP 2 — F                                   READ TRADE FACTØR DATA. VAR=ØNE
   1 — H  WEIGHT — J            -2.0 — K    -30.0 — L           G
   2      RANGE                 -1.0          1.0
   3      IØC                   -5.0        -10.0
   4      WHWT                  -.055       -.160
        Blank — M
ZIP B — N                                   P — EXECUTE RANKING & SENSITIVITY ANALYSIS
ZIP 9 — Q                                   STØP — R
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PAGE LINE | LABEL | OPERATION | OPERAND | A | IDENTIFICATION

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FIGURE II-8

RWM - PARTIAL REPLACEMENT OF INPUT DATA

PROGRAM | ROUTINE | NAME | UNIT | EXT. | DATE | PAGE OF

UNCLASSIFIED

1. To replace a single Trade Factor or Factors

```
ZIP  2 1                                  REPLACE SINGLE TRADE FACTOR(S)
     3   IØC                     .1         .4
       Blank
```

2. To replace a single System Name or Names

```
ZIP  6 1                                  REPLACE SINGLE SYSTEM NAME(S)
     5         NEW NAME -->           <--  NEW NAME
     8         ETC.                           ETC.
       Blank
```

3. To replace a single System or Systems Data

```
ZIP  7 1                                  REPLACE SYSTEMS DATA
     5        1.162     33.30     44.70
     8        1.281     38.25     44.92
       Blank
```


(II-22 Reverse Side Blank)

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5. OUTPUT

(U) Output of the RWM includes a title page, copies of ZIP code control cards used, miscellaneous initialization data, copies of input data tables, and three output tables:

(a) SYSTEM RANK AND SCORE

(b) SENSITIVITY MATRIX

(c) SYSTEM RANKING SENSITIVITY - RANK BOUND

These are discussed in detail as to format and meaning in Figures II-9 thru II-13.

FIGURE II-9

RWM OUTPUT - PAGES 1, 2, 3.

ITEM	DESCRIPTION
A	PCODE. A one line label printed at the top of each numbered page.
B	A Five Line Title.
C	Miscellaneous Constants. Not Used.
D	System Number
E	System Name (or coded information)
F	System Rank. (1 is best)
G	SCORE. In E-Format, i.e. 4.765E+02 means 476.5 which is the "equivalent" WORTH of System 1 after adjustment by the Trade Factors. The system is better than, equal to, or less than the "baseline" system according to whether the SCORE is greater than, equal to, or less than the input value BWORTH = 453.0 shown in Figure II-3 and in Figure II-10.

FIGURE II-9 (Continued)

```
DATA.PGM=RWM          RELATIVE WORTH MODEL (SAMPLE)                PAGE    1
                                                               RUN = 74-01-18
                                                                      A
```

```
                      RWM
                      VOUGHT SYSTEMS DIVISION
                      LTV AEROSPACE CORPORATION                   B
                      DALLAS, TEXAS 75222
```

```
DATA.PGM=RWM          RELATIVE WORTH MODEL (SAMPLE)                PAGE    2  A
                                                               RUN = 74-01-18

     MISC         1          0          0          0          0          0 C        0
     XMISC   1.0000      0.0        0.0        0.0        0.0        0.0        0.0 C
```

```
                                                                   PAGE    3
DATA.PGM=RWM          RELATIVE WORTH MODEL (SAMPLE)            RUN = 74-01-18  A
SYSTEM RANK AND SCORE                                                PAGE    1
```

NO. D	SYSTEM DESCRIPTION E	RANK F	SCORE G
1	LIQ ROC -24(LIGHT)	6	4.765E 02
2	LIQ ROC - 1(LIGHT)	4	4.875E 02
3	LIQ ROC - 2(LIGHT)	1	4.890E 02
4	LIQ ROC -5(LIGHT)	1	4.890E 02
5	LIQ ROC -23(LIGHT)	5	4.825E 02
6	LIQ ROC - 6(LIGHT)	3	4.985E 02
7	LIQ ROC -40(HVY)	12	4.415E 02
8	LIQ ROC - 1(HVY)	9	4.525E 02
9	LIQ ROC -20(HVY)	10	4.480E 02
10	LIQ ROC - 9(HVY)	10	4.480E 02
11	LIQ ROC - 2(HVY)	8	4.530E 02
12	LIQ ROC - 6(HVY)	7	4.535E 02
13	SOL ROC - 5(HVY)	17	4.365E 02
14	SOL ROC - 3(HVY)	14	4.375E 02
15	SOL ROC - 7(HVY)	16	4.370E 02
16	SOL ROC - 4(HVY)	13	4.380E 02
17	SOL ROC -14(HVY)	18	4.295E 02
18	SOL ROC - 8(HVY)	14	4.375E 02

FIGURE II-10

RWM OUTPUT - SENSITIVITY MATRIX PRINT CONTROL, & NAMELIST NAM1

ITEM	DESCRIPTION
A	PCODE. A one line label printed at the top of each numbered page.
B	SENSITIVITY MATRIX Page number. If large enough it will be split and put on several pages.
C	Rank number of system in a particular SENSITIVITY MATRIX column.
D	System number of a system in a particular SENSITIVITY MATRIX column.
E	System number of a system in a particular SENSITIVITY MATRIX row to which it is being compared in a given column.
F	Entries in the SENSITIVITY MATRIX. These are the k_{pq} defined in equation (5) in section II. 2, where if the entry is greater than 1.0 the system numbered in D is always better than the system numbered in column E. For example, System 2 is not always better than System 5, but is always better than System 1.
G, H	ZIP Code 3 and Print options as read in.
J, K	ZIP Code 1, NAMELIST NAM1, Base Worth & Base System Variables as read in. See Figure II-3.

FIGURE II- 10 (Continued)

DATA.PGM=RWM RELATIVE WORTH MODEL (SAMPLE) PAGE 4 RUN = 74-01-18 (A)

SENSITIVITY MATRIX PAGE 1 (B)

RANK NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 (C)	17
SYS NO.	3	4	6	2	5	1	12	11	8	9	10	7	16	14	18	15 (D)	13
4	99.99																
6	0.04	0.04															
2	0.12	0.12	0.04														
5	0.52	0.52	99.99	0.20													
1	1.00	1.00	0.48	99.99	0.24												
12	2.03	2.03	6.99	1.13	5.79	0.77											
11	7.19	7.19	2.03	1.97	1.69	1.34	0.04										
8	2.09	2.09	1.20	6.99	1.00	4.80	0.04	0.04									
9	8.19	8.19	2.31	2.26	1.97	1.63	0.44	99.99	0.36								
10	8.19	8.19	2.31	2.26	1.97	1.63	0.44	99.99	0.36	99.99							
7	2.71	2.71	1.57	9.19	1.37	6.99	0.48	0.92	99.99	0.52	0.52						
16	3.40	3.40	1.84	1.80	1.62	1.40	0.69	1.50	0.64	1.00	1.00	0.16					
14	1.87	1.87	1.27	3.33	1.12	2.60	0.46	0.69	1.50	0.47	0.47	0.40	0.04				
18	1.87	1.87	3.40	1.25	3.00	0.97	1.60	0.69	0.43	0.47	0.47	0.11	0.04	0.0			
15	3.47	3.47	1.87	1.84	1.65	1.44	0.73	1.60	0.69	1.10	1.10	0.20	99.99	0.04	0.04		
13	1.91	1.91	1.30	3.40	1.15	2.67	0.49	0.73	1.60	0.51	0.51	0.50	0.12	99.99	0.04	0.04	
17	2.16	2.16	3.93	1.45	3.53	1.17	2.43	1.04	0.66	0.82	0.82	0.34	0.68	0.32	99.99	0.60	0.28
(E)	(F)	(F)															(F)

(G)

```
ZIP  3 0 0          0    0    0    0    0 READ OUTPUT PRINT OPTIONS
(H) 1    1    1    0    1    1

ZIP  1 0 0          0    0    0    0    0 READ BASE WORTH & BASE SYSTEM VARIABLES
&NAM1 (J)
ISCORE=         1,MATRX=        1,IBOUND=       1,NTOP=       200,ITRADE=       1,IDATA=       1,BWORTH=
  453.00000    ,XBASE=  12.000000   ,  105.00000   ,  3.0000000   ,  1100.0000   , 0.0         , 0.0         ,
 0.0 (K)       , 0.0           , 0.0           , 0.0           , 0.0           , 0.0         , 0.0         , 0.0     ,
 0.0           , 0.0           , 0.0           , 0.0           , 0.0           , 0.0
&END
```

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FIGURE II-11

RWM OUTPUT - RANK BOUNDS TABLE

ITEM	DESCRIPTION
A	PCODE. A one line label printed at the top of each numbered page.
B	Table title and page number.
C	Rank bounds (and size of SENSITIVITY MATRIX) depends on number of systems specified in J. 4 of Figure II-3. In this case, all 18 systems were used.
D, E	System number and name. Limited to the number shown in C.
F	Upper Rank Bound (Highest rank is 1).
G	Average Rank. Same F in Figure II-9.
H	Lower Rank Bound (limited to number in C).
NOTE:	For System No. 6 the numbers 1, 3, 5 mean that while its SCORE based on the average trade factor gives it a rank of 3, the error bounds and their interaction with all the systems means that there are some conditions within the bounds of uncertainty for which the rank could be as high as 1 or as low as 5.

FIGURE II-11 (Continued)

PAGE 5

DATA.PGM=RWM RELATIVE WORTH MODEL (SAMPLE) RUN = 74-01-18 A

SYSTEM RANKING SENSITIVITY - RANK BOUND B PAGE 1

(BASED ON SYSTEMS RANKED 1 THROUGH 18) C

NO. D	SYSTEM DESCRIPTION E	UPPER BOUND F	AVERAGE RANK G	LOWER BOUND H
1	LIQ ROC -24(LIGHT)	2	6	8
2	LIQ ROC - 1(LIGHT)	1	4	5
3	LIQ ROC - 2(LIGHT)	1	1	6
4	LIQ ROC -5(LIGHT)	1	1	6
5	LIQ ROC -23(LIGHT)	2	5	7
6	LIQ ROC - 6(LIGHT)	1	3	5
7	LIQ ROC -40(HVY)	8	12	18
8	LIQ ROC - 1(HVY)	6	9	15
9	LIQ ROC -20(HVY)	8	10	17
10	LIQ ROC - 8(HVY)	8	10	17
11	LIQ ROC - 2(HVY)	7	8	13
12	LIQ ROC - 6(HVY)	6	7	16
13	SOL ROC - 6(HVY)	9	17	18
14	SOL ROC - 3(HVY)	8	14	17
15	SOL ROC - 7(HVY)	11	16	18
16	SOL ROC - 4(HVY)	8	13	17
17	SOL ROC -14(HVY)	10	18	18
18	SOL ROC - 8(HVY)	7	14	17

FIGURE II-12

RWM OUTPUT - TRADE FACTOR TABLE

ITEM	DESCRIPTION
A	PCODE. A one line label printed at the top of each numbered page.
B	Table title and page number.
C	Trade Factor number, corresponds to variable number in SYSTEMS DATA.
D	Trade Factor name
E	Minimum Trade Factor (as input)
F	Average Trade Factor (as calculated)
G	Maximum Trade Factor (as input)

NOTE: Trade Factors have negative signs if the corresponding variable is less desirable for large values, e.g. large WEIGHT is less desirable than small WEIGHT.

FIGURE II-12 (Continued)

PAGE 6

CATA.PGM=RWM RELATIVE WORTH MODEL (SAMPLE) (A) RUN = 74-01-18

PARAMETER TRADE FACTOR DATA (B) PAGE 1

NO.	NAME	MINIMUM	AVERAGE	MAXIMUM
(C)	(D)	(E)	(F)	(G)
1	WEIGHT	-3.000E 00	-1.550E 01	-2.800E 01
2	RANGE	1.000E 00	1.000E 00	1.000E 00
3	IOC	-6.000E 00	-1.600E 01	-2.600E 01
4	WHWT	-5.450E-03	-1.000E-02	-1.455E-02

FIGURE II-13

RWM OUTPUT - SYSTEM DATA TABLE

ITEM	DESCRIPTION
A	PCODE. A one line lable printed at the top of each numbered page.
B	Table title and page number
C	System Number
D	System WEIGHT (as input)
E	System RANGE (as input)
F	System YEARS TO IOC (as input)
G	System WARHEAD WEIGHT (as input)

FIGURE II-13 (Continued)

PAGE 7

DATA.PGM=RWM ' RELATIVE WORTH MODEL (SAMPLE) RUN = 74-01-18

S Y S T E M D A T A B A PAGE 1

SYS NO. C	WEIGHT D	RANGE E	IOC F	WHWT G
1	1.100E 01	1.130E 02	3.000E 00	1.100E 03
2	1.100E 01	1.240E 02	3.000E 00	1.100E 03
3	1.200E 01	1.410E 02	3.000E 00	1.100E 03
4	1.200E 01	1.410E 02	3.000E 00	1.100E 03
5	1.300E 01	1.500E 02	3.000E 00	1.100E 03
6	1.300E 01	1.560E 02	3.000E 00	1.100E 03
7	1.100E 01	8.900E 01	3.000E 00	2.200E 03
8	1.100E 01	1.000E 02	3.000E 00	2.200E 03
9	1.200E 01	1.110E 02	3.000E 00	2.200E 03
10	1.200E 01	1.110E 02	3.000E 00	2.200E 03
11	1.200E 01	1.150E 02	3.000E 00	2.200E 03
12	1.300E 01	1.320E 02	3.000E 00	2.200E 03
13	1.100E 01	1.020E 02	4.000E 00	2.200E 03
14	1.100E 01	1.010E 02	4.000E 00	2.200E 03
15	1.200E 01	1.160E 02	4.000E 00	2.200E 03
16	1.200E 01	1.170E 02	4.000E 00	2.200E 03
17	1.300E 01	1.240E 02	4.000E 00	2.200E 03
18	1.300E 01	1.320E 02	4.000E 00	2.200E 03

SECTION III

OPERATING PROCEDURES

1. GENERAL

(U) This section defines the operating procedures necessary for utilization of the Relative Worth Model. The RWM source deck consists of approximately 1000 cards. To facilitate small modifications with a minimum of recompilation, it is recommended that the load module be placed on a user's library. This will also greatly reduce card handling requirements for production run utilization.

1.1 SEM Compilation and Link Edit to a User's Library

(U) The IBM System 360/65 will compile the RWM in less than two minutes of elapsed time. Less than 1000 lines of printout are generated. No object deck is generated by this operation. Figure III-1 shows the typical JCL setup required for RWM compilation, link edit and placing the load module on a private deck pack. If the RWM load module required subsequent modification, only the subroutine(s) that were changed need to be loaded as "RWM Fortran Source Decks."

1.2 User's Library

(U) The JCL shown in Figure III-1 defines the User's Library as the partitioned data set SYS1. DS5CSEAA on the private disk pack VOL = SER = RIPTDE. The RWM load module is stored under the member name RWM.

1.3 RWM Execution

(U) Figure III-2 defines a typical IBM 360/65 JCL and deck setup required for executing a RWM load module resident on a user's library. Execution time requirements are set by the scope of the input problem, but is on the order of 1 minute for each ranking of 100 systems with 20 variables each. The volume of printout generated is set by the input print option and may range from a low of about six pages per ranking to a high of about 20 pages.

1.4 Limits

(U) The RWM has been dimensioned to take a maximum of 200 systems and/or 20 trade factors.

2. RANKING

(U) The setup of data decks for the obtaining of a ranking and sensitivity analysis has already been described in detail in Section II.4. This includes control parameters, print control, initialization of miscellaneous parameters, Trade Factor input, and System names, and System Data.

(U) The model is a single load module without any link overlay. After all required data has been input, a ZIP-8 control card produces an execution of ranking and sensitivity analysis as discussed in Section II.4.7. A way of doing several parametric variations of some set of parameters in a single computer run is also discussed in Section II.4.7.

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80 COLUMN CODING AND DATA FORM 0-63797

PROGRAM
FIGURE III-1

ROUTINE
RWM COMPILATION AND LINK EDIT TO A USER'S LIBRARY

NAME
UNIT
EXT.
PAGE OF

```
//             JOB ( - format is system dependent - )                                  X
//                 SEATIDE,MSGLEVEL=1
//RWM          EXEC FØRTGCL,PARM.FØRT='ID,NØDECK,LIST,MAP',                            X
//                 REGIØN.FØRT=140K,                                                   X
//                 PARM.LKED='ØVLY,LET,MAP,LIST,SIZE=(128K,28K)',                      X
//                 REGIØN.LKED=140K
//FØRT.SYSLIN DD  SPACE=(CYL,(5,1))
//FØRT.SYSIN DD *
                      { RWM FORTRAN SOURCE DECKS }
/*
//LKED.SYSLMØD DD DSN=SYS1.DSSCSEAA,UNIT=2314,VØL=SER=RIPTOE,DISP=ØLD,                 X
//                 SPACE=(CYL,(5,5))
//LKED.SYSIN DD *
    INCLUDE SYSLMØD(RWM)
    ENTRY MAIN
    NAME RWM(R)
/*
```


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80 COLUMN CODING AND DATA FORM 0-83797

NAME

PROGRAM

FIGURE III-2

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DATE

ROUTINE

RWM EXECUTION JOB CONTROL LANGUAGE

PAGE OF

TYPE | STATEMENT NO. | CONT. | FORTRAN STATEMENT | FORTRAN | IDENTIFICATION

LOCATION | CONT. | OPERATION | ADDRESS, TAG, DECREMENT | MAP

PAGE SERIAL | A | B | COBOL

```
//         JØB ( - format is system dependent - )
//STEP3    EXEC PGM=RWM,REGIØN=080K,TIME=20
//STEPLIB  DD DSN=SYS1.DSSCSEAA,DISP=SHR
//SYSUDUMP DD SYSØUT=A
//FT06F001 DD SYSØUT=A
//FT07F001 DD SYSØUT=B
//FT05F001 DD *

        RWM - DATA DECK

/*
```

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PAGE LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

VOUGHT MISSILES
AND SPACE COMPANY

TITLE	
SOURCE PROGRAM LISTING (RWM)	Appendix A NO. DATE 8 July 1971

TABLE OF CONTENTS

PREPARED BY L. D. Gregory

APPROVED BY L.D. Gregory

PAGE A-1 OF A-16

```
C LA0305  RELATIVE  WORTH  MODEL
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCO.FORT.IV
C
      INTEGER  ZCODE,ZIP
      COMMON/TRADE1/ E1( 20), T1( 20), T1MAX( 20), T1MIN( 20)
      COMMON/MAIN3/ ISCORE,IBOUND,NSYSTM,NPARAM,MATRX,NRANK,ITRADE,IDATA
      COMMON/MAIN1/ BWORTH, XBASE( 20)
      COMMON/MAIN2/ SNAME(200,10),  PARAM( 20,4),  X(200,20)
      COMMON/INOUT/ NLINE, NPAGE, PCODE(20), TRASH(20)
      DIMENSION ZCODE(19)
      DIMENSION  WORD(8),HOLD(10)
      EQUIVALENCE  (NBRNCH,ZCODE(2)), (ISET,ZCODE(3))
      DATA BLANK4/4H    /
      DATA  ZIP / 'ZIP ' /
      NAMELIST /NAM1/ ISCORE, MATRX, IBOUND, NTOP, ITRADE, IDATA,
     1                BWORTH, XBASE
 1000 FORMAT(16I5)
 1010 FORMAT(5X,16I5)
 1002 FORMAT( I5, 5X, 2(2A4,2X), 2E10.3)
 1012 FORMAT(5X,I5,5X,2(2A4,2X),1P2E10.3)
 1004 FORMAT(1X,A3,19A4)
 1014 FORMAT(6X,A3,19A4)
 1005 FORMAT(I5,5X,10A4)
 1006 FORMAT(I5,1X,2I2,7E10.3)
 1111 FORMAT(1H1)
 1700 FORMAT(     A4,3I2,I10,4I5,10A4)
 1710 FORMAT(/6X,A4,3I2,I10,4I5,10A4)
      NDPAR= 20
      NDSYS= 200
      ITRADE=1
      IDATA= 1
      IBOUND=0
      MATRX= 0
      NTOP=NDSYS
      ISCORE  =  1
      BWORTH=0.
      DO 110  I=1,NDPAR
  110 XBASE(I)=0.
   11 WRITE(6,1111)
C
C     READ BRANCH CONTROL ZIP CODE
C
   10 READ (5,1700) ZCODE
      WRITE(6,1710) ZCODE
      IF(ZCODE(1) .NE. ZIP) GO TO 9
      IF(NBRNCH.GT.9) GO TO 9
      IF(NBRNCH.LT.1) GO TO 9
      GO TO(1,2,3,4,5,6,7,8,9),NBRNCH
C
C     ENTER BASELINE DATA AND OUTPUT OPTION FLAGS
C
    1 READ (5,NAM1)
      WRITE(6,NAM1)
      GO TO 11
C
```

```
C     ENTER TRADE FACTOR DATA
C
    2 IF(ISET.GT.0) GO TO 20
      DO 21 I=1,NDPAR
      T1MAX(I) = 0.
      T1MIN(I) = 0.
      DO 19 J=1,4
   19 PARAM(I,J)=BLANK4
   21 CONTINUE
      NPARAM=1
   20 IF(ISET .EQ. 2) CALL COMBNE (ISET)
      IF(ISET .EQ. 3) GO TO 10
   18 READ (5,1002) I, (HOLD(J),J = 1,6)
      WRITE(6,1012) I, (HOLD(J),J = 1,6)
      IF(I)22,10,23
   22 IREAD=-1
      I=-I
      GO TO 24
   23 IREAD=0
   24 IF(I.GT.NDPAR) GO TO 9
      NPARAM=MAX0(NPARAM,I)
      T1MAX(I) = HOLD(6)
      T1MIN(I) = HOLD(5)
      IF(HOLD(1) .EQ. BLANK4) GO TO 29
      DO 27 J = 1,4
   27 PARAM(I,J) = HOLD(J)
   29 IF (IREAD)10,18,18
C
C     RESET OUTPUT OPTIONS
C
    3 READ (5,1000) ISCORE, MATRX,IBOUND,NTOP,ITRADE,IDATA
      WRITE(6,1010) ISCORE, MATRX,IBOUND,NTOP,ITRADE,IDATA
      IF(NTOP.LE.0) NTOP=NDSYS
      GO TO 10
C
C     RESET RUN IDENTIFICATION PCODE
C
    4 READ (5,1004)(PCODE(I),I=1,20)
      WRITE(6,1014)(PCODE(I),I=1,20)
      NPAGE=0
      GO TO 10
C
C     RESET PCODE, TITLE PAGE, COMMENTS
C
    5 CALL START
      GO TO 11
C
C     ENTER SYSTEM DESCRIPTIONS - NAMES
C
    6 READ(5,1005) I,(HOLD(J),J=1,10)
      IF(ISET.GT.0) GO TO 666
      DO 6666 K=1,NDSYS
      DO 6666 J=1,10
 6666 SNAME(K,J) = BLANK4
  666 ISET=1
```

```
      IF(I)61,10,62                                                     MAIN0940
   61 IREAD=-1                                                          MAIN0950
      I=-I                                                              MAIN0960
      GO TO 64                                                          MAIN0970
   62 IREAD=0                                                           MAIN0980
   64 IF(I.GT.NDSYS) GO TO 9                                            MAIN0990
      DO 65 J=1,10                                                      MAIN1000
   65 SNAME(I,J)=HOLD(J)                                                MAIN1010
      IF(IREAD)10,6,6                                                   MAIN1020
C                                                                       MAIN1030
C     ENTER SYSTEM DATA                                                 MAIN1040
C                                                                       MAIN1050
    7 IF(ISET.GT.0)GO TO(71,7003,7021,7750), ISET                       MAIN1060
      NSYSTM=1                                                          MAIN1070
   71 KSYSTM=1                                                          MAIN1080
      IREF=0                                                            MAIN1090
   70 READ(5,1006) I,JA,JB,(HOLD(J),J=1,7)                              MAIN1100
      IF(I)72,10,73                                                     MAIN1110
   72 IREAD=-1                                                          MAIN1120
      I=-I                                                              MAIN1130
      GO TO 74                                                          MAIN1140
   73 IREAD=0                                                           MAIN1150
   74 IF(I.GT.NDSYS) GO TO 9                                            MAIN1160
      IF(JA.GT.NDPAR) GO TO 9                                           MAIN1170
      IF(JB.GT.NDPAR) GO TO 9                                           MAIN1180
      IF(JA.GT.JB) GO TO 9                                              MAIN1190
      NSYSTM=MAX0(NSYSTM,I)                                             MAIN1200
      IF(I.EQ.IREF) GO TO 75                                            MAIN1210
      IREF=I                                                            MAIN1220
      IA=0                                                              MAIN1230
   78 IF(JA.NE.0)  GO TO 76                                             MAIN1240
      JA=IA+1                                                           MAIN1250
      JB=MIN0(IA+7,NDPAR)                                               MAIN1260
   76 K=0                                                               MAIN1270
      DO 77 J=JA,JB                                                     MAIN1280
      K=K+1                                                             MAIN1290
   77 X(I,J)=HOLD(K)                                                    MAIN1300
      IF(IREAD)10,70,70                                                 MAIN1310
   75 IA=IA+7                                                           MAIN1320
      GO TO 78                                                          MAIN1330
C                                                                       MAIN1340
C     EXECUTE RANKING                                                   MAIN1350
C                                                                       MAIN1360
    8 NRANK=MIN0(NSYSTM,NTOP)                                           MAIN1370
      CALL RANK                                                         MAIN1380
      GO TO 11                                                          MAIN1390
C                                                                       MAIN1400
C     EXIT - TERMINATION OF ROUTINE                                     MAIN1410
C                                                                       MAIN1420
    9  CALL EXIT                                                        MAIN1430
      GO TO 10                                                          MAIN1440
C                                                                       MAIN1450
C       DATA MATRIX MODIFICATION SECTION                                MAIN1460
C                                                                       MAIN1470
      DIMENSION LST(26),AL(26),LS(200),LP(40),CDE(9)                    MAIN1480
```

```
      DATA DSH,ZRO/1H-,1H0/,CDE/2HAD,2HMU,2HPO,2HNO,2HRE,
     1   2HSU,2HDI,2HRO,2H  /
 7003 K=0
C
C     READ SYSTEM INDEX LIST
C
 7004 READ (5,7000)(LST(I),AL(I),I=1,26)
      WRITE(6,7700)(LST(I),AL(I),I=1,26)
      DO 7001 I=1,26
      IL=LST(I)
      IF(IL.EQ.0) GO TO 7C10
      ALP=AL(I)
      IF(IL.EQ.10.AND.ALP.EQ.ZRO) IL=100
      K=K+1
      LS(K)=IL
      IF(ALP.NE.DSH) GO TO 7001
      IL=IL+1
      JL=LST(I+1)-1
      IF(JL.EQ.9.AND.AL(I+1).EQ.ZRO)JL=99
      DO 7002 J=IL,JL
      K=K+1
 7002 LS(K)=J
 7001 CONTINUE
      GO TO 7004
 7010 IF(K.EQ.0) GO TO 10
      KS=K
C
C     READ MODIFICATION OPERATION AND PARAMETER INDEX LIST
C
 7021 READ (5,7070) CODE,ADUM,ADUM2,FACTOR,(LST(I),AL(I),I=1,16)
      WRITE(6,7770) CODE,ADUM,ADUM2,FACTOR,(LST(I),AL(I),I=1,16)
      DO 7020 I =1,9
      IF(CODE.EQ.CDE(I)) GO TO 7030
 7020 CONTINUE
      GO TO 9
 7030 KCODE=I
      GO TO(7041,7041,7041,7041,7021,7042,7043,7044,7003),KCODE
 7042 FACTOR = - FACTOR
      KCODE = 1
      GO TO 7041
 7043 FACTOR = 1./ FACTOR
      KCODE = 2
      GO TO 7041
 7044 FACTOR = 1. / FACTOR
      KCODE = 3
 7041 K =0
      DO 7011 I =1,16
      IL=LST(I)
      IF(IL.EQ.0) GO TO 7100
      K = K+1
      LP(K) = IL
      IF(AL(I).NE.DSH) GO TO 7011
      IL= IL+1
      JL = LST(I+1) -1
      DO 7012 J=IL,JL
```

```
      K = K+1
 7012 LP(K) = J
 7011 CONTINUE
 7100 KP = K
      IF(KCODE.EQ.4) GO TO 7600
      DO 7050 I=1,KS
      IL = LS(I)
      DO 7050 J=1,KP
      JL= LP(J)
      GO TO (7051,7052,7053,7021,7021), KCODE
 7051 X(IL,JL) = X(IL,JL) + FACTOR
      GO TO 7050
 7052 X(IL,JL)=  X(IL,JL) * FACTOR
      GO TO 7050
 7053 X(IL,JL) = X(IL,JL) ** FACTOR
 7050 CONTINUE
      GO TO 7021
 7600 LBLOCK=LP(2)
      NORM=LP(1)
      DO 7650 I=1,KS
      IL=LS(I)
      DO 7650 J=3,KP
      JL=LP(J)
      IREF=(JL-1)*LBLOCK
      IK=IREF+1
      JK=IREF+LBLOCK
      NO=IREF+NORM
      FACT=X(IL,NO)/FACTOR
      DO 7650 KL=IK,JK
      IF(KL.EQ.NO) GO TO 7650
      X(IL,KL)=X(IL,KL)*FACT
 7650 CONTINUE
      GO TO 7021
 7000 FORMAT (26(I2,A1))
 7700  FORMAT(5X,26(I2,A1))
 7070 FORMAT(A2,2A4,E10.3,10X,16(I2,A1))
 7770 FORMAT(5X,A2,2A4,E10.3,10X,16(I2,A1))
 7750 READ (5,1000) I1,I2,J1,J2,NS
      IF (NS.GT.0) NSYSTM = NS
      IF(I1.LE.0.AND.NS.LE.0) GO TO 10
      IF(I1.LE.0) GO TO 7750
      DO 7751 I = I1, I2
      READ (5,7752) ( X(I,J), J = J1, J2)
 7752 FORMAT (10X,14F5.0)
 7751 CONTINUE
      GO TO 7750
      END


      SUBROUTINE START
C
C
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCD.FORT.IV
C       A UTILITY SUBROUTINE
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C       PURPOSE - TO READ,                                              STAR0060
C 1. PCODE.  ONE 79 COLUMN LABEL.  WILL BE PRINTED AT TOP OF EACH PAGE. STAR0070
C 2. TITLE.  EXACTLY FIVE CARDS (OMIT COLUMN 1).  PRINTED ON PAGE 1.    STAR0080
C 3. COMMENTS.  UP TO 520 CARDS OF COMMENTS, PROBLEM DESCRIPTION, ETC.  STAR0090
C               WILL BE PRINTED ON PAGE 2, 50 LINES TO THE PAGE.        STAR0100
C               TWO SUCCESSIVE BLANK CARDS DENOTES END OF COMMENTS.     STAR0110
C 4. MISC(7), 7 INTEGERS (10X,7I10).  XMISC(7), 7 REALS (10X,7F10.4)    STAR0120
      COMMON/INOUT/ NLINE, NPAGE, PCODE(20), TRASH(20)                  STAR0130
C                                                                       STAR0140
      COMMON/TITLE1/TITLE(100),MISC(7),XMISC(7)                         STAR0150
C                                                                       STAR0160
      DATA BLANK/ 4H    /                                               STAR0170
C                                                                       STAR0180
 1000 FORMAT(1X,A3,19A4)                                                STAR0190
 1004 FORMAT(10X,7I10)                                                  STAR0200
 1006 FORMAT(10X,7F10.0)                                                STAR0210
 2000 FORMAT(1H1,71X, 4HPAGE,I4/6X,A3,19A4//)                           STAR0220
 2002 FORMAT(6X,A3,19A4)                                                STAR0230
 2004 FORMAT(12X, 4HMISC,7I10)                                          STAR0240
 2006 FORMAT(11X, 5HXMISC,7F10.4)                                       STAR0250
 2010 FORMAT(///////////)                                               STAR0260
 2020 FORMAT(//40H ERROR. MORE THAN 520 LINES OF COMMENTS//)            STAR0270
CXX                                                                     STAR0280
CXX                                                                     STAR0290
    1 READ(5,1000) PCODE,TITLE                                          STAR0300
      NPAGE = 1                                                         STAR0310
CXX                                                                     STAR0320
      WRITE(6,2000) NPAGE,PCODE                                         STAR0330
      WRITE(6,2010)                                                     STAR0340
      WRITE(6,2002) TITLE                                               STAR0350
CXX                                                                     STAR0360
      NFLAG = 0                                                         STAR0370
      NLINE = 0                                                         STAR0380
    4 NPAGE = NPAGE + 1                                                 STAR0390
      WRITE(6,2000) NPAGE,PCODE                                         STAR0400
CXX                                                                     STAR0410
   10 NLINE = NLINE + 1                                                 STAR0420
      READ(5,1000) TRASH                                                STAR0430
CXX                                                                     STAR0440
      DO 20 I = 1,20                                                    STAR0450
      IF (TRASH(I).NE.BLANK)                 GO TO 26                   STAR0460
   20 CONTINUE                                                          STAR0470
      NFLAG = NFLAG + 1                                                 STAR0480
      IF(NFLAG.GE.2)                         GO TO 36                   STAR0490
      GO TO 28                                                          STAR0500
CXX                                                                     STAR0510
   26 NFLAG = 0                                                         STAR0520
CXX                                                                     STAR0530
   28 WRITE(6,2002) TRASH                                               STAR0540
      IF(NLINE.LE.520)                       GO TO 30                   STAR0550
      WRITE(6,2020)                                                     STAR0560
      CALL EXIT                                                         STAR0570
CXX                                                                     STAR0580
   30 K = NLINE - 1                                                     STAR0590
      IF (MOD(K,50).EQ.49)                   GO TO 4                    STAR0600
```

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      GO TO 10                                                          STAR0610
CXX                                                                     STAR0620
 36   READ(5,1004) MISC                                                 STAR0630
      READ(5,1006)XMISC                                                 STAR0640
      WRITE(6,2004)MISC                                                 STAR0650
      WRITE(6,2006)XMISC                                                STAR0660
CXX                                                                     STAR0670
      RETURN                                                            STAR0680
      END                                                               STAR0690


      SUBROUTINE COMBNE (KSET)                                          COMB0010
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCD.FORT.IV               COMB0020
C                                                                       COMB0030
      COMMON/MAIN3/ ISCORE,IBOUND,NSYSTM,NPARAM,MATRX,NRANK,ITRADE,IDATACOMB0040
      COMMON/MAIN2/ TITLE(200,10),  PARAM( 20,4),  X(200,20)           COMB0050
      COMMON/TRADE1/ EI( 20), TI( 20), TIMAX( 20), TIMIN( 20)           COMB0060
      DIMENSION VNAME(40,2), CNAME(10,2), V(40), C(10), EV(40), EC(10)  COMB0070
    1 READ (5,1000) IV,JV, NV , IC, JC, NC  ,NE                          COMB0080
      IF (NV.GT. 0) NV1 = NV                                            COMB0090
      IF (NC.GT. 0) NC1 = NC                                            COMB0100
      IF (IV  .GT. 0) READ(5,1001)((VNAME(I,J),J=1,2),V(I),EV(I),I=IV,JV)COMB0110
      IF (IC  .GT. 0) READ(5,1001)((CNAME(I,J),J=1,2),C(I),EC(I),I=IC,JC)COMB0120
      IF(NE.GT.0) GO TO 300                                             COMB0130
      IF(IC.GT.0.OR.IV.GT.0.OR.NV.GT.0.OR.NC.GT.0) GO TO 1              COMB0140
      DO 100 I = 1, NV1                                                 COMB0150
      V1 = V(I)                                                         COMB0160
      EV1= EV(I)                                                        COMB0170
      VN1 = VNAME(I,1)                                                  COMB0180
      VN2 = VNAME(I,2)                                                  COMB0190
      K = NC1*(I - 1)                                                   COMB0200
      DO 100 J = 1, NC1                                                 COMB0210
      K = K + 1                                                         COMB0220
      IF(K .GT.  20) GO TO 200                                          COMB0230
      PARAM(K,1) = VN1                                                  COMB0240
      PARAM(K,2) = VN2                                                  COMB0250
      PARAM(K,3) = CNAME(J,1)                                           COMB0260
      PARAM(K,4) = CNAME(J,2)                                           COMB0270
      TIMIN(K) = -V1 * C(J)                                             COMB0280
  100 TIMAX(K) =  EV1 + EC(J)                                           COMB0290
      KSET = 3                                                          COMB0300
      NPARAM = K                                                        COMB0310
      RETURN                                                            COMB0320
  200 WRITE(6,1002) K                                                   COMB0330
 1002 FORMAT(1H1,6X,4HK = ,I5,17HEXCEEDS  20 LIMIT )                    COMB0340
      CALL EXIT                                                         COMB0350
 1000 FORMAT(16I5)                                                      COMB0360
 1001 FORMAT(10X,2A4,12X,2E10.3)                                        COMB0370
  300 READ(5,1003) KV,LV,KC,LC,ERROR                                    COMB0380
      IF(KV.LE.0) GO TO 301                                             COMB0390
      DO 310 I=KV,LV                                                    COMB0400
  310 EV(I)=ERROR                                                       COMB0410
 1003 FORMAT(4I5,F5.0)                                                  COMB0420
  301 IF(KC.LE.0) GO TO 1                                               COMB0430
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      DO 320 I=KC,LC                                                    COMB0440
  320 EC(I)=ERROR                                                       COMB0450
      GO TO 1                                                           COMB0460
      END                                                               COMB0470


      SUBROUTINE RANK                                                   RANK0010
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCD.FORT.IV               RANK0020
C                                                                       RANK0030
C                                                                       RANK0040
      COMMON/MAIN3/ ISCORE,IBOUND,NSYSTM,NPARAM,MATRX,NRANK,ITRADE,IDATARANK0050
      COMMON/MAIN2/ TITLE(200,10),  PARAM( 20,4),  X(200,20)            RANK0060
      COMMON/RANOUT/ IUPTEK(200),TEKAVG(200),JAVTEK(200),LOWTEK(200)    RANK0070
      COMMON/RANK1/ ZTEST, JA, JB, IGNORE( 20), IGNORT( 20)             RANK0080
      COMMON/TRADE1/ E1( 20), T1( 20), T1MAX( 20), T1MIN( 20)           RANK0090
      COMMON/INOUT/ NLINE, NPAGE, PCODE(20), TRASH(20)                  RANK0100
      DIMENSION IAVTEK(200)                                             RANK0110
      ZTEST = 1.E-20                                                    RANK0120
      CALL TRADE                                                        RANK0130
      JA =1                                                             RANK0140
      JB = NPARAM                                                       RANK0150
      CALL SCORE(TEKAVG)                                                RANK0160
      CALL SORT(TEKAVG, IAVTEK, JAVTEK )                                RANK0170
      CALL OUTPUT(1)                                                    RANK0180
      IF (IBOUND .LE. 0) GO TO 10                                       RANK0190
      JA = 1                                                            RANK0200
      JB = NPARAM                                                       RANK0210
      CALL SENSIT (TEKAVG, IAVTEK, IUPTEK, LOWTEK)                      RANK0220
      CALL OUTPUT(2)                                                    RANK0230
   10 IF (ITRADE .GT. 0) CALL OUTPUT(3)                                 RANK0240
      IF (IDATA .GT. 0) CALL OUTPUT(4)                                  RANK0250
      RETURN                                                            RANK0260
      END                                                               RANK0270


      SUBROUTINE TRADE                                                  TRAD0010
C                                                                       TRAD0020
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCD.FORT.IV               TRAD0030
C                                                                       TRAD0040
      COMMON/MAIN3/ ISCORE,IBOUND,NSYSTM,NPARAM,MATRX,NRANK,ITRADE,IDATATRAD0050
      COMMON/MAIN2/ TITLE(200,10),  PARAM( 20,4),  X(200,20)            TRAD0060
      COMMON/RANK1/ ZTEST, JA, JB, IGNORE( 20), IGNORT( 20)             TRAD0070
      COMMON/TRADE1/ E1( 20), T1( 20), T1MAX( 20), T1MIN( 20)           TRAD0080
      DO 100 J = 1, NPARAM                                              TRAD0090
      YAL = T1MIN(J)                                                    TRAD0100
      IF (ABS(YAL) - ZTEST) 40, 41, 41                                  TRAD0110
   40 IGNORT(J) = 1                                                     TRAD0120
      IGNORE(J) = 1                                                     TRAD0130
      GO TO 100                                                         TRAD0140
   41 YAU = T1MAX(J)                                                    TRAD0150
      IF (YAU * YAL - ZTEST) 42, 42, 43                                 TRAD0160
   43 T1(J) = (YAU + YAL) * .5                                          TRAD0170
      E1(J) = ABS(YAU - YAL) * .5                                       TRAD0180
```

```
      GO TO 99                                                          TRAD0190
   42 T1(J) = YAL                                                       TRAD0200
      PCT = ABS(YAU)                                                    TRAD0210
      IF (PCT - ZTEST) 10, 11, 11                                       TRAD0220
   10 TIMAX(J) = YAL                                                    TRAD0230
      E1(J) = 0.                                                        TRAD0240
      GO TO 99                                                          TRAD0250
   11 E1J = ABS(YAL * PCT)                                              TRAD0260
      TIMIN(J) = YAL - E1J                                              TRAD0270
      TIMAX(J) = YAL + E1J                                              TRAD0280
      E1(J) = E1J                                                       TRAD0290
   99 IGNORT(J) = 0                                                     TRAD0300
      IGNORE(J) = 0                                                     TRAD0310
      IF (E1(J).LT. ZTEST) IGNORE(J) = 1                                TRAD0320
  100 CONTINUE                                                          TRAD0330
      RETURN                                                            TRAD0340
      END                                                               TRAD0350


      SUBROUTINE SCORE (XSCORE)                                         SCOR0010
C                                                                       SCOR0020
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCD.FORT.IV                SCOR0030
C                                                                       SCOR0040
      COMMON/MAIN3/ ISCORE,IBOUND,NSYSTM,NPARAM,MATRX,NRANK,ITRADE,IDATASCOR0050
      COMMON/MAIN1/ BWORTH, XBASE( 20)                                  SCOR0055
      COMMON/MAIN2/ TITLE(200,10),  PARAM( 20,4),  X(200,20)            SCOR0060
      COMMON/RANK1/ ZTEST, JA, JB, IGNORE( 20), IGNORT( 20)             SCOR0070
      COMMON/TRADE1/ E1( 20), T1( 20), TIMAX( 20), TIMIN( 20)           SCOR0080
      DIMENSION XSCORE(200)                                             SCOR0090
      DO 410 I = 1, NSYSTM                                              SCOR0100
  410 XSCORE(I) = BWORTH                                                SCOR0110
      DO 400 J = JA ,JB                                                 SCOR0120
      IF (IGNORT(J))  10, 10, 400                                       SCOR0130
   10 T1J = T1(J)                                                       SCOR0140
      BASE=T1J*XBASE(J)                                                 SCOR0145
      DO 420 I = 1, NSYSTM                                              SCOR0150
  420 XSCORE(I)=XSCORE(I)+X(I,J)*T1J-BASE                               SCOR0160
  400 CONTINUE                                                          SCOR0170
      RETURN                                                            SCOR0180
      END                                                               SCOR0190


      SUBROUTINE SORT (XSCORE,IRANK,ISYSTM)                             SORT0010
C                                                                       SORT0020
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCD.FORT.IV                SORT0030
C HIGHEST SCORE GIVES HIGHEST RANK (CONTROL BY SORT0130,0210,0340)      SORT0035
C                                                                       SORT0040
      DIMENSION  XSCORE(200), IRANK(200), ISYSTM(200)                   SORT0050
      COMMON/MAIN3/ ISCORE,IBOUND,NSYSTM,NPARAM,MATRX,NRANK,ITRADE,IDATASORT0060
      DO 201 J = 1, NSYSTM                                              SORT0070
  201 IRANK(J) = J                                                      SORT0080
  202 I = 1                                                             SORT0090
  203 IA = I + 1                                                        SORT0100
```

```
      JB = IRANK(IA)                                                    SORT0110
      JA = IRANK(I)                                                     SORT0120
      IF(XSCORE(JA)-XSCORE(JB))205,204,204                              SORT0130
  205 IRANK(I) = JB                                                     SORT0140
      IRANK(IA) = JA                                                    SORT0150
      J = I                                                             SORT0160
  206 JA = J-1                                                          SORT0170
      IF (JA)204,204,208                                                SORT0180
  208 IA = IRANK(J)                                                     SORT0190
      IB = IRANK(JA)                                                    SORT0200
      IF(XSCORE(IA)-XSCORE(IB))204,204,209                              SORT0210
  209 IRANK(J) = IB                                                     SORT0220
      IRANK(JA) = IA                                                    SORT0230
      J = J-1                                                           SORT0240
      GO TO 206                                                         SORT0250
  204 I = I+1                                                           SORT0260
      IF (I-NSYSTM)203,250,250                                          SORT0270
  250 J = IRANK(1)                                                      SORT0280
      ISYSTM(J) = 1                                                     SORT0290
      IREF = 1                                                          SORT0300
      REF = XSCORE(J)                                                   SORT0310
      DO 260 I = 2, NSYSTM                                              SORT0320
      J = IRANK(I)                                                      SORT0330
      IF(REF-XSCORE(J))11,11,10                                         SORT0340
   10 REF = XSCORE(J)                                                   SORT0350
      IREF = I                                                          SORT0360
      ISYSTM(J) = I                                                     SORT0370
      GO TO 260                                                         SORT0380
   11 ISYSTM(J) = IREF                                                  SORT0390
  260 CONTINUE                                                          SORT0400
      RETURN                                                            SORT0410
      END                                                               SORT0420


      SUBROUTINE SENSIT (XSCORE,IRANK,IUPPER,LOWER)                     SENS0010
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCD.FORT.IV                SENS0020
C HIGHEST SCORE GIVES HIGHEST RANK (CONTROL BY SENS0350)                SENS0030
C                                                                       SENS0040
      DIMENSION  XSCORE(200),IRANK(200),IUPPER(200),LOWER(200)          SENS0050
      COMMON/WORK/ SENS( 20)                                            SENS0060
      COMMON/MAIN3/ ISCORE,IBOUND,NSYSTM,NPARAM,MATRX,NRANK,ITRADE,IDATASENS0070
      COMMON/MAIN2/ TITLE(200,10),  PARAM( 20,4),  X(200,20)            SENS0080
      COMMON/RANK1/ ZTEST, JA, JB, IGNORE( 20), IGNORT( 20)             SENS0090
      COMMON/TRADE1/ E1( 20), T1( 20), T1MAX( 20), T1MIN( 20)           SENS0100
      COMMON/INOUT/ NLINE, NPAGE, PCODE(20), TRASH(20)                  SENS0110
 9000 FORMAT (1H1,78X,4HPAGE,I3)                                        SENS0120
 9001 FORMAT (7X, A3,19A4)                                              SENS0130
 2000 FORMAT (1H0,4X,19HSENSITIVITY  MATRIX,55X,4HPAGE, I3)             SENS0140
 2001 FORMAT (//5X,8HRANK NO., I2, 16(4X,I3))                           SENS0150
 2002 FORMAT (5X,7HSYS NO., I3, 16(4X,I3))                              SENS0160
 2003 FORMAT (6X,I3,17(1X,F6.2))                                        SENS0170
      DO 700 I = 1,NRANK                                                SENS0180
      J = IRANK(I)                                                      SENS0190
      IUPPER(J) = 1                                                     SENS0200
```

```
700 LOWER(J) = NRANK
    MINUS = NRANK-1
    LINE = 0
    IPAGE = 1
    ICOL = 1
101 IROW=ICOL+1
    NCOL = ICOL+16
    KCOL = MINO(NCOL,MINUS)
100 DO 600 I = IROW,NRANK
    JCOL = MINO(NCOL,I-1)
    NQ = IRANK(I)
    SCOREQ = XSCORE(NQ)
    DO 610 K = ICOL,JCOL
    NP = IRANK(K)
    DPQ = XSCORE(NP) - SCOREQ
    EPQ = 0.
    DO 620 J = JA,JB
    IF (IGNORE(J))90,90,620
 90 EPQ = EPQ + ABS(E1(J) * (X(NP,J)- X(NQ,J)))
620 CONTINUE
    IF (EPQ-ZTEST)20,21,21
 20 RATIO=99.99
    IF (ZTEST-DPQ)32,32,50
 21 RATIO = DPQ/EPQ
    IF (RATIO-99.99)40,41,41
 41 RATIO = 99.99
    GO TO 32
 40 IF (RATIO-1.)50,50,32
 32 LOWER(NP) = LOWER(NP)-1
    IUPPER(NQ) = IUPPER(NQ)+1
 50 SENS(K) = RATIO
610 CONTINUE
    IF (MATRX)600,600,72
 72 IF (LINE)76,75,77
 75 NPAGE = NPAGE+1
    WRITE(6,9000)NPAGE
    WRITE(6,9001)(PCODE(L),L=1,20)
800 WRITE(6,2000) IPAGE
802 LINE=4
    GO TO 78
 76 LINE = -LINE
 78 WRITE(6,2001)(K,K=ICOL,KCOL)
    WRITE(6,2002)(IRANK(K),K=ICOL,KCOL)
    LINE = LINE+4
 77 WRITE(6,2003)NQ, (SENS(K),K=ICOL,JCOL)
    LINE = LINE+1
    IF (LINE-60)600,81,81
 81 LINE = 0
    IPAGE = IPAGE+1
600 CONTINUE
    ICOL = ICOL + 17
    IF (ICOL-NRANK)111,500,500
111 IF (MATRX)101,101,112
112 IF (LINE-40)93,91,91
 91 LINE = 0
```

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      IPAGE = IPAGE+1                                                   SENS0760
      GO TO 101                                                         SENS0770
   93 LINE = -LINE                                                      SENS0780
      GO TO 101                                                         SENS0790
  500 RETURN                                                            SENS0800
      END                                                               SENS0810


      SUBROUTINE OUTPUT (K)                                             OUTP0010
C PGM=NU7(RWM) L.D.GREGORY  VERS. 1  JULY71 EBCD.FORT.IV                OUTP0020
C                                                                       OUTP0030
C                                                                       OUTP0040
      COMMON/WORK/ RNDATA( 20)                                          OUTP0050
      COMMON/TRADE1/ E1( 20), T1( 20), TIMAX( 20), TIMIN( 20)           OUTP0060
      COMMON/RANK1/ ZTEST, JA, JB, IGNORE( 20), IGNORT( 20)             OUTP0070
      COMMON/MAIN3/ ISCORE,IBOUND,NSYSTM,NPARAM,MATRX,NRANK,ITRADE,IDATAOUTP0080
      COMMON/MAIN2/ TITLE(200,10),  PARAM( 20,4),   X(200,20)           OUTP0090
      COMMON/RANOUT/ IUPTEK(200),TEKAVG(200),JAVTEK(200),LOWTEK(200)    OUTP0100
      COMMON/INOUT/ NLINE, NPAGE, PCODE(20), TRASH(20)                  OUTP0110
 9000 FORMAT (1H1,78X,4HPAGE,I3)                                        OUTP0120
 9001 FORMAT (7X,A3,19A4)                                               OUTP0130
 9002 FORMAT(/)                                                         OUTP0140
 2000 FORMAT (1H0,5X,21HSYSTEM RANK AND SCORE, 52X,4HPAGE, I3)          OUTP0150
 2002 FORMAT (1H0, 5X, 42HNO.    S Y S T E M   D E S C R I P T I O N,   OUTP0160
     1           9X, 30HRANK         SCORE                , //)         OUTP0170
 2011 FORMAT(6X,I3,2X,10A4,6X,I3,7X,1PE10.3)                            OUTP0180
 3000 FORMAT (1H0,5X,39HSYSTEM RANKING SENSITIVITY - RANK BOUND,        OUTP0190
     1           34X,4HPAGE, I3)                                        OUTP0200
 3001 FORMAT (1H0,5X,35H(BASED ON SYSTEMS RANKED  1 THROUGH,I3,1H),     OUTP0210
     1           /60X,23HUPPER   AVERAGE   LOWER)                       OUTP0220
 3002 FORMAT (6X,42HNO.     S Y S T E M    D E S C R I P T I O N,       OUTP0230
     1            12X,23HBOUND     RANK      BOUND, //    )             OUTP0240
 3004 FORMAT (6X,I3,2X,10A4,10X,I3,6X,I3,6X,I3)                         OUTP0250
 5000 FORMAT (1H0,5X,27HPARAMETER TRADE FACTOR DATA,46X,4HPAGE,I3)      OUTP0260
 5006 FORMAT(1H0,5X,3HNO.,2X,4HNAME,18X,31HMINIMUM     AVERAGE     MAXIMOUTP0270
     1UM,  //)                                                          OUTP0280
 5002 FORMAT(6X,I3,2(2X,2A4), 3X,8HNOT USED)                            OUTP0290
 5003 FORMAT(6X,I3,2(2X,2A4), 3(2X,1PE10.3))                            OUTP0300
 6000 FORMAT(1H0,5X,21HS Y S T E M   D A T A,  52X,4HPAGE,I3)           OUTP0310
 6001 FORMAT (1H0,5X,3HSYS, 11(3X,2A4))                                 OUTP0320
 6002 FORMAT(6X,3HNO.,11(3X,2A4))                                       OUTP0330
 6003 FORMAT(6X,I3,11(  1PE11.3 ))                                      OUTP0340
      IPAGE = 0                                                         OUTP0350
      GO TO (100,333,55,60),K                                           OUTP0360
  100 IROW = 1                                                          OUTP0370
      KROW=51                                                           OUTP0380
  111 JROW = MIN0(KROW,NSYSTM)                                          OUTP0390
  112 IPAGE = IPAGE+1                                                   OUTP0400
      NPAGE = NPAGE+1                                                   OUTP0410
      WRITE(6,9000)NPAGE                                                OUTP0420
      WRITE(6,9001)(PCODE(M),M=1,20)                                    OUTP0430
      GO TO (2,3,5,6),K                                                 OUTP0440
    2 WRITE(6,2000) IPAGE                                               OUTP0450
      WRITE(6,2002)                                                     OUTP0460
```

```
   21 DO 200 I = IROW,JROW                                              OUTP0470
      WRITE(6,2011) I,(TITLE(I,J),J=1,10),JAVTEK(I), TEKAVG(I)          OUTP0480
  200 CONTINUE                                                          OUTP0490
      GO TO 113                                                         OUTP0500
  333 JROW=0                                                            OUTP0510
      I=1                                                               OUTP0520
      GO TO 112                                                         OUTP0530
    3 WRITE(6,3000) IPAGE                                               OUTP0540
      WRITE(6,3001)NRANK                                                OUTP0550
      WRITE(6,3002)                                                     OUTP0560
   33 JA=JAVTEK(I)                                                      OUTP0570
      IF(JA-NRANK)30,30,31                                              OUTP0580
   30 WRITE (6,3004) I,(TITLE(I,J),J=1,10),IUPTEK(I),JA, LOWTEK(I)      OUTP0590
  305 JROW=JROW+1                                                       OUTP0600
   31 I = I + 1                                                         OUTP0610
      IF(I-NSYSTM)32,32,999                                             OUTP0620
   32 IF(JROW.LT.51) GO TO 33                                           OUTP0630
  304 JROW=0                                                            OUTP0640
      GO TO 112                                                         OUTP0650
  113 IF (NSYSTM-JROW)999,999,114                                       OUTP0660
  999 RETURN                                                            OUTP0670
  114 IROW=JROW+1                                                       OUTP0680
      JROW = NSYSTM                                                     OUTP0690
      GO TO 112                                                         OUTP0700
   55 JROW=51                                                           OUTP0710
      IROW = 1                                                          OUTP0720
      GO TO 112                                                         OUTP0730
    5 WRITE(6,5000)IPAGE                                                OUTP0740
      WRITE(6,5006)                                                     OUTP0750
      JROW = MINO(JROW, NPARAM)                                         OUTP0760
      DO 500 J = IROW, JROW                                             OUTP0770
      IF(IGNORT(J).EQ.1) GO TO 505                                      OUTP0780
      WRITE(6,5003) J,(PARAM(J,I),I=1,4   ),TIMIN(J),TI(J),TIMAX(J)     OUTP0790
      GO TO 500                                                         OUTP0800
  505 WRITE(6,5002) J,(PARAM(J,I),I=1,4   )                             OUTP0810
  500 CONTINUE                                                          OUTP0820
      IF(JROW .GE. NPARAM) RETURN                                       OUTP0830
      IROW = JROW + 1                                                   OUTP0840
      JROW=JROW+51                                                      OUTP0850
      GO TO 112                                                         OUTP0860
   60 KCOL = 11                                                         OUTP0870
      IROW=1                                                            OUTP0880
      KROW=51                                                           OUTP0890
   62 ICOL = 1                                                          OUTP0900
      JCOL = MINO(KCOL,NPARAM)                                          OUTP0910
      GO TO 111                                                         OUTP0920
    6  WRITE(6,6000)IPAGE                                               OUTP0930
      WRITE(6,6001)((PARAM(I,J),J=1,2),I=ICOL,JCOL)                     OUTP0940
      WRITE(6,6002)((PARAM(I,J),J=3,4),I=ICOL,JCOL)                     OUTP0950
      WRITE(6,9002)                                                     OUTP0960
      DO 600 I = IROW,JROW                                              OUTP0970
      DO 601 J = ICOL,JCOL                                              OUTP0980
      IF (IGNORT(J))65,65,66                                            OUTP0990
   65 RNDATA(J) = X(I,J)                                                OUTP1000
      GO TO 601                                                         OUTP1010
```

```
   66 RNDATA(J) = 0.                                                    OUTP1020
  601 CONTINUE                                                          OUTP1030
      WRITE(6,6003) I,(RNDATA(M),M=ICOL,JCOL)                           OUTP1040
  600 CONTINUE                                                          OUTP1050
      IF (NPARAM-JCOL)67,67,68                                          OUTP1060
   68 ICOL = JCOL + 1                                                   OUTP1070
      JCOL = JCOL + 11                                                  OUTP1080
      JCOL = MINO(JCOL, NPARAM)                                         OUTP1090
      GO TO 112                                                         OUTP1100
   67 IF (NSYSTM-JROW)999,999,602                                       OUTP1110
  602 IROW=JROW+1                                                       OUTP1120
      KROW=NSYSTM                                                       OUTP1130
      GO TO 62                                                          OUTP1140
      END                                                               OUTP1150
```

TITLE

RWM SAMPLE PROBLEM

NO. Appendix B

DATE January 1974

TABLE OF CONTENTS

PREPARED BY L. D. Gregory

APPROVED BY

APPENDIX B

RWM SAMPLE PROBLEM (U)

1. INTRODUCTION

(U) The objective of Appendix B is to present a general technique for estimating Trade Factors. These were defined in Section II in the body of the report and are the constrained derivatives of some baseline variable x_b with respect to each of the system variables x_j ($j = 1$ to n). The technique for estimating these Trade Factors is presented in terms of an example, and the rank and rank bounds are included to show the effect of the estimates made.

2. SYSTEM DATA

(U) The example chosen to illustrate the estimation of Trade Factors is taken from the cruise missile concept studies reported in Volume IIIA of the SEATIDE documentation. After an initial screening, six high ranking candidates were chosen in each of three concept types: Liquid (light payload), Liquid (heavy payload), Solid (heavy payload). These were then put into the Relative Worth Model for ranking and sensitivity analyses. The trade factors used are shown in Figure B-1, and the eighteen systems with their respective weight, range, years to IOC, and warhead weight are shown in Figure B-2. System 1-6 are Liquid rocket (light payload), 7-12 are Liquid Rocket (heavy payload), and 13-18 are Solid Rocket (heavy payload) types. The systems data is from the CM-CGSM which generated the candidates, except years to IOC which was added later.

FIGURE B-1

RWM TRADE FACTOR INPUTS

PAGE

DATA.PGM=RWM RELATIVE WORTH MODEL (SAMPLE) RUN = 74-01-18

PARAMETER TRADE FACTOR DATA PAGE

NO.	NAME	MINIMUM	AVERAGE	MAXIMUM
1	WEIGHT	-3.000E 00	-1.550E 01	-2.800E 01
2	RANGE	1.000E 00	1.000E 00	1.000E 00
3	IOC	-6.000E 00	-1.600E 01	-2.600E 01
4	WHWT	-5.450E-03	-1.000E-02	-1.455E-02

(B-4 Reverse side blank)

FIGURE B-2

RWM SYSTEM DATA INPUTS

PAGE

DATA.PGM=RWM   RELATIVE WORTH MODEL (SAMPLE)   RUN = 74-01-1

S Y S T E M   D A T A   PAGE

SYS NO.	WEIGHT	RANGE	IOC	WHWT
1	1.100E 01	1.130E 02	3.000E 00	1.100E 03
2	1.100E 01	1.240E 02	3.000E 00	1.100E 03
3	1.200E 01	1.410E 02	3.000E 00	1.100E 03
4	1.200E 01	1.410E 02	3.000E 00	1.100E 03
5	1.300E 01	1.500E 02	3.000E 00	1.100E 03
6	1.300E 01	1.560E 02	3.000E 00	1.100E 03
7	1.100E 01	8.900E 01	3.000E 00	2.200E 03
8	1.100E 01	1.000E 02	3.000E 00	2.200E 03
9	1.200E 01	1.110E 02	3.000E 00	2.200E 03
10	1.200E 01	1.110E 02	3.000E 00	2.200E 03
11	1.200E 01	1.160E 02	3.000E 00	2.200E 03
12	1.300E 01	1.320E 02	3.000E 00	2.200E 03
13	1.100E 01	1.000E 02	4.000E 00	2.200E 03
14	1.100E 01	1.010E 02	4.000E 00	2.200E 03
15	1.200E 01	1.160E 02	4.000E 00	2.200E 03
16	1.200E 01	1.170E 02	4.000E 00	2.200E 03
17	1.300E 01	1.240E 02	4.000E 00	2.200E 03
18	1.300E 01	1.320E 02	4.000E 00	2.200E 03

3. TRADE FACTORS

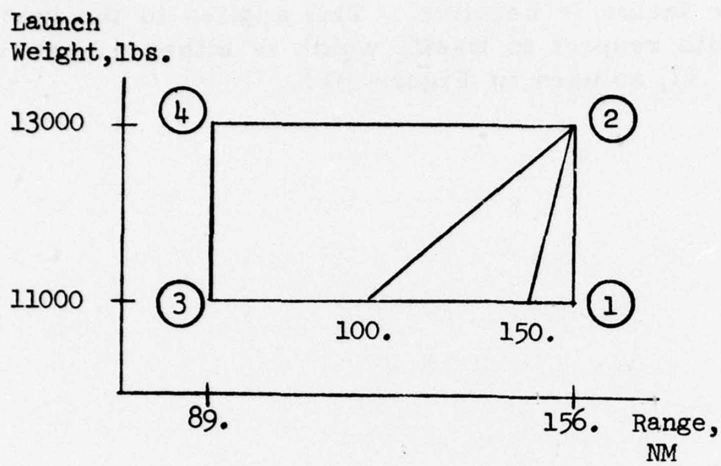
(U) Estimation of Trade Factors proceeds as follows: Total missile range is chosen as the baseline variable x_b. This choice is arbitrary as far as the model is concerned, but is best done to enhance the use of relations best known to the analyst. In Figure B-3 each of the other variables are "traded" against the baseline variable "Range".

(U) Launch weight vs range is shown schematically at the top of Figure B-3. The eighteen systems from Figure B-2 would appear as points inside the rectangle as shown since 89 NM is the smallest range, and 156 NM is the largest range, and all weights are between 11,000 and 13,000 lbs. Note that launch weight is handled in thousands of pounds in the input from Figure B-2, hence must be so treated here when it comes to units for the trade factor. Rectangles for each of the other variables are next shown vs Range in Figure B-3. In the estimation of trade factors it is important to remember that the estimation need be valid only for the ranges of variables represented by the sides of the rectangles.

(U) The four corners of each rectangle should now be labeled from (1) to (4) in order of preference. For launch weight, Corner (1) is where launch weight is low and total range is high. The opposite corner is automatically Corner (4). The choice of Corner (2) is critical. For launch weight, in this example, it is felt that a range of 89 NM for an air launched missile is unacceptably low, while a weight of 13,000 lbs. is not unacceptable. Hence the upper right (156, 13,000) is preferred to lower left (89, 11000) for the launch weight rectangle. In this example, it so happens that in all three rectangles, the upper right was chosen as Corner (2). A special comment is due on the rectangle for Warhead Weight. Ordinarily increasing warhead weight is deemed desirable, hence the upper right corner would be Corner (1). But, if the analyst felt that the heavy warhead produced needless "overkill" and preferred the smaller size, then he could label as shown in this example.

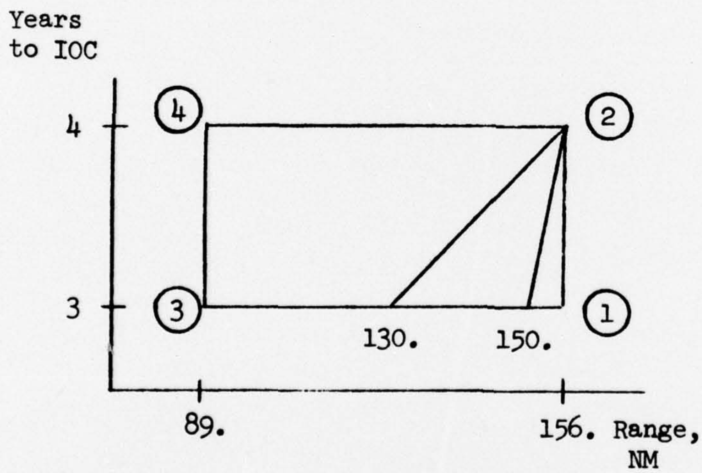
(U) Next, establish between Corner (1) and Corner (3) a point of equal preference to Corner (2). The analyst may have difficulty in deciding exactly where this point is (or two different analysts may not agree), but upper and lower bounds may be selected as shown. For launch weight, one might feel strongly enough about the importance of reducing weight to accept a 100 NM range. Another might not accept less than 150 NM. These two points are then connected to Corner (2), and these lines become bounds on the line of equal preference. The slopes are the trade factors needed by the RWM. These are computed and shown beside each rectangle.

FIGURE B - 3
RWM TRADE FACTORS (EXAMPLE)



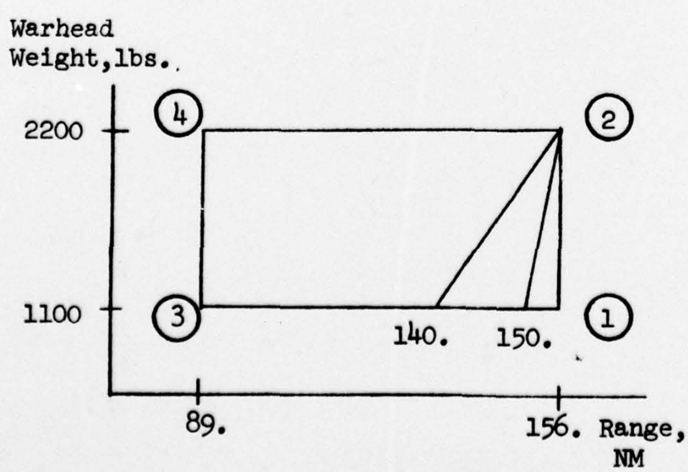
$t_{LW} = -6./2. = -3.0$

$= -56./2. = -28.0$



$t_{IOC} = -6./1. = -6.0$

$= -26./1. = -26.0$



$t_{WW} = -6./1100. = -.00545$

$t_{WW} = -16./1100. = -.01455$

(U) Note that the sign of the trade factors is chosen by the sign convention that if the variable (e.g. launch weight) is such that low values are perferred, the trade factor is negative. This applies to the trade factor of the variable with respect to itself, which is either +1 or -1. In this example it is a +1, as used in Figure B-1.

4. RANK AND RANK BOUNDS

(U) Use of the preceding data in the RWM produced the computer output shown in Figure B-4, giving system name, rank, and rank bounds as discussed in Section II-5 in the body of the report. Note: The system "name" was coded to allow traceback to the candidate identity in the CGSM, e.g., LIQ ROC-24 (LIGHT) means liquid rocket concept number 24, using the light (1100 pound) warhead.

(U) To illustrate how the rank bound and related systems data may be displayed, the systems were tabulated in Figure B-5. It is seen that System 7, for example, has the least range (89 n. mi.) and ranks between 8 and 18. The highest ranking systems, concepts number 3 and 4, have identical range (141 n. mi.), identical weight (12, 000 lbs.), and identical warhead weight (1100 lbs.). In general, for this sample problem, the light warhead weight concepts rank higher than the heavier warhead concepts. Concepts with the greatest range also tend to rank higher than concepts with lesser range, and liquid rockets tend to rank higher than solid rockets.

FIGURE B-4
RWM RANK AND RANK BOUND OUTPUTS

DATA.PGM=RWM RELATIVE WORTH MODEL (SAMPLE) PAGE RUN = 74-01-1

SYSTEM RANKING SENSITIVITY - RANK BOUND PAGE

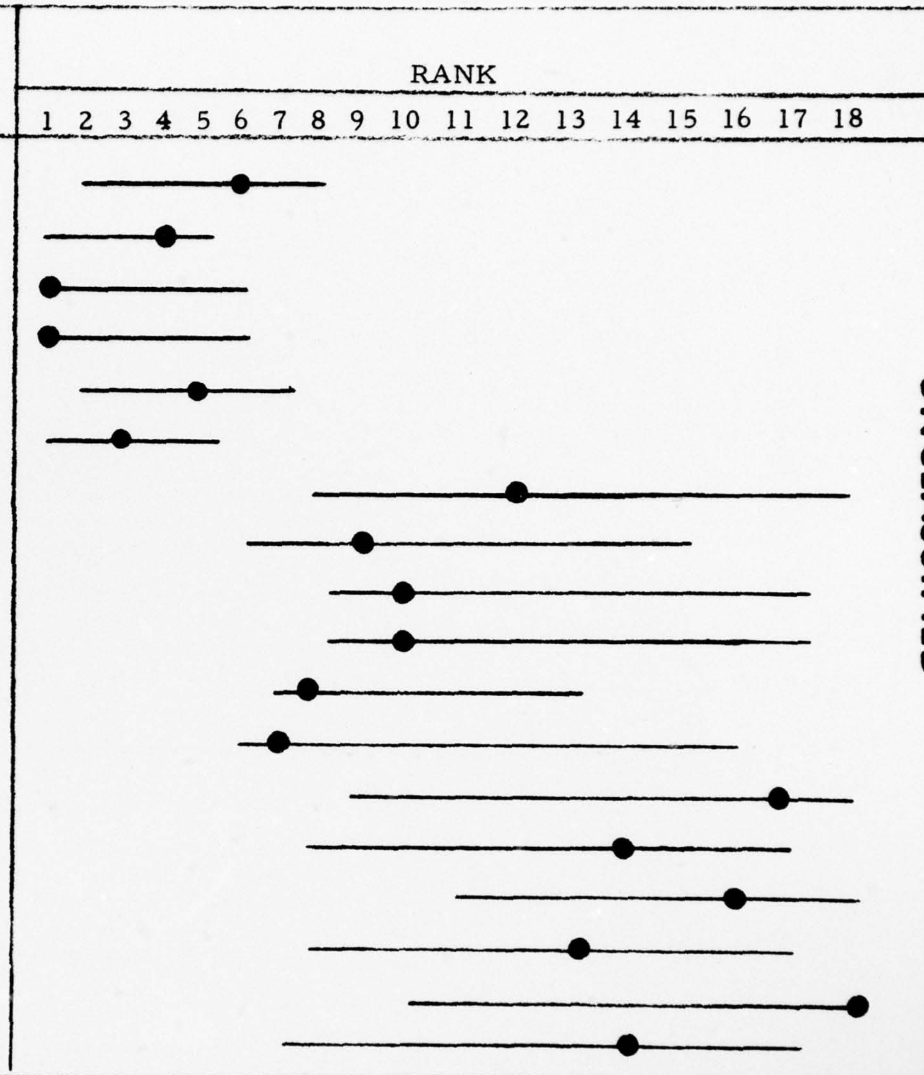
(BASED ON SYSTEMS RANKED 1 THROUGH 18)

NO.	SYSTEM DESCRIPTION	UPPER BOUND	AVERAGE RANK	LOWER BOUND
1	LIQ ROC -24(LIGHT)	2	6	8
2	LIQ ROC - 1(LIGHT)	1	4	5
3	LIQ ROC - 2(LIGHT)	1	1	6
4	LIQ ROC -5(LIGHT)	1	1	6
5	LIQ ROC -23(LIGHT)	2	5	7
6	LIQ ROC - 6(LIGHT)	1	3	5
7	LIQ ROC -43(HVY)	8	12	18
8	LIQ ROC - 1(HVY)	6	9	15
9	LIQ ROC -20(HVY)	8	10	17
10	LIQ ROC - 8(HVY)	8	10	17
11	LIQ ROC - 2(HVY)	7	8	13
12	LIQ ROC - 6(HVY)	6	7	16
13	SOL ROC - 6(HVY)	9	17	18
14	SOL ROC - 3(HVY)	8	14	17
15	SOL ROC - 7(HVY)	11	16	18
16	SOL ROC - 4(HVY)	8	13	17
17	SOL ROC -14(HVY)	10	18	18
18	SOL ROC - 8(HVY)	7	14	17

FIGURE B-5

EXAMPLE - RANKED HIGH VALUE CRUISE MISSILE SYSTEMS (U)

SYSTEM NUMBER	WEIGHT (K - lbs)	RANGE (NM)	WARHEAD WT (lbs)
①	11	113	1100
②	11	124	1100
③	12	141	1100
④	12	141	1100
⑤	13	150	1100
⑥	13	156	1100
⑦	11	89	2200
⑧	11	100	2200
⑨	12	111	2200
⑩	12	111	2200
⑪	12	116	2200
⑫	13	132	2200
△13	11	100	2200
△14	11	101	2200
△15	12	116	2200
△16	12	117	2200
△17	13	124	2200
△18	13	132	2200



• Propulsion Type:
○ Liquid Rocket
△ Solid Rocket

Average Rank
Upper bound
Lower bound